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BEACH CUSPS

A FREQUENT feature of our New England beaches is a succession of stony or gravelly cusps with sharp points toward the water, situated on the upper part of the beach where the waves play only at high stages of the tide. My attention was first called to these cusps by Mr. J. B. Woodworth, of Harvard University, under whose direction the general view, Fig. 1, was taken for the U. S. Geological Survey. Subsequent study on Lynn Beach, Mass., where I obtained twenty instantaneous wave photographs, has satisfied me that on that particular shore the cusps must be ascribed to the agency of the seaweed piled up on the beach, modifying the action of the greater waves. The successive stages of construction shed so clear a light on the local forms, and the weed control has seemed so clear through a great variety of details observed on this beach during more than two years, that it seems time to call the attention of other observers to the point involved. Any beach photograph may have a record on it of some stage of these beach cusps.

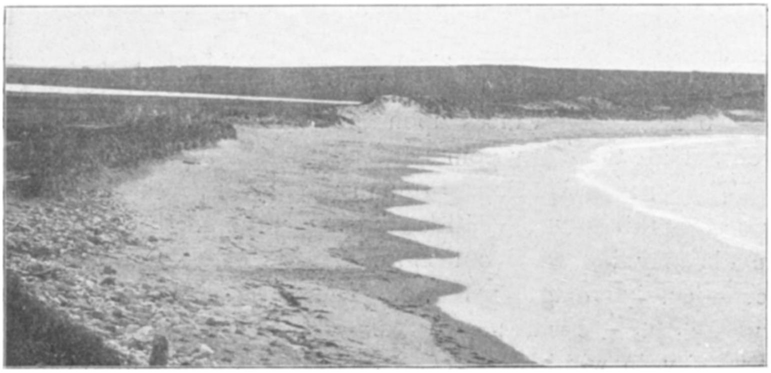

FIG. 1.—Westquage Beach, R. I.

The portion of Lynn Beach where these studies were made is at the junction of the Nahant barrier beach with the mainland, about one hundred yards north of Hotel Nahant. It opens to the Atlantic a little south of east and is on the Boston Bay sheet of the topographic map, in latitude 42°, 27′ 30″, longitude west 70° 56′ 7″. A masonry wall with a concrete walk above here caps the beach. Just below this is a mass of rounded stones from two to six inches in diameter, which have been flung up in storms. These are attached to seaweed, having been derived from the bottom off shore.[1] This belt of cobblestones passes into the sand of the beach proper by the series of cusps above mentioned. The seaward side of the heap of cobbles is, as it were, eaten out in bays, twenty to thirty feet wide with residual points of cobbles between. In the bays, the slope descends one foot in four to the almost level beach of fine sea sand. Along a line roughly tangent to the bay heads, and thus cutting across the stony promontories between, there is found an almost continuous wall of seaweed. The bays in the cobble line are floored with a gravel of texture intermediate between the stones above and the sands below. The stony points terminate in slopes much steeper than the bay floors. The gravel of the bay floors itself advances upon the beach in a series of capes, well outside the stony points and alternating with them.

The outer undulating margin of the gravel points on the sand is usually thinly strewn with cobbles from the belt above. These details may be made out more clearly with the help of the accompanying diagram, Fig. 2. The constant *recurrence* of bay and point as one walks along the beach suggests that there is a regularity in width of intervals. This is not so, however, on Lynn Beach, as appears from the diagram, measures from point to point along the beach being 21, 20, 18, 16, 22, 17, 6, 7, and 22 paces. Fainter cusps farther south toward Nahant show similar irregularity. It might be said, however, that on Lynn Beach they are commonly about twenty paces wide.

The work of the waves on the beach depends on their magnitude and direction, and on the stage of the tide. The magnitude of the waves varies primarily with the wind. The great rollers that tumble up a beach some days of calm are due simply to a distant wind whose effect is transmitted faster through the water than through the air. For beach work, however, we must distinguish two orders in the magnitude of waves that follow each other even in a brief period. Anyone who visits a beach may satisfy himself that at fairly regular intervals there occurs a great wave, far overtopping the average in height and extent of advance up the beach. Now this great wave is as much more efficient than its fellows for beach work in ordinary weather, as the work of a single storm outweighs months of normal tides in building and modifying features of shore topography. As regards the stage of the tide, in a similar way, spring tides are the occasions of maximum beach work in average weather. This is especially true in all that concerns the upper beach line, where our gravel cusps are situated. All the waves, great and ordinary, have an excess of shoreward over off-shore movement during rising tide. Generally speaking it is thus during the rising of the tide that objects are driven up the beach, and during the fall that they are drawn out seaward, unless left stranded, as must happen in most cases, since both forces, though opposite in direction, have least intensity at the shoreward margin of the beach.

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[1] SHALER: National Geographic Monographs, Beaches and Marshes, p. 144.

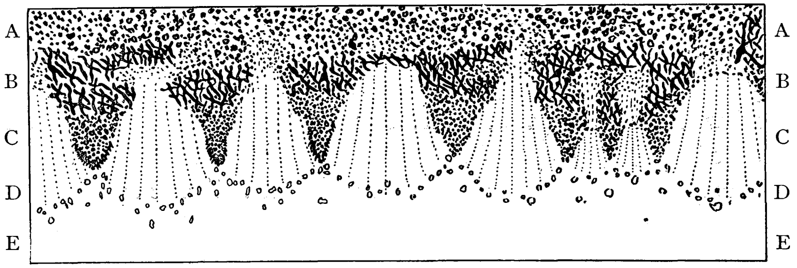

FIG. 2.—Diagram of Beach Cusps.

AA Zone of Cobbles.
BB Zone of Seaweed.
CC Stony Cusps.
DD Gravel Cusps.
EE Flat Beach of Sand.

It results from these considerations that the greatest amount of stones and seaweed will be flung up on the upper beach on the rise of a spring tide when a strong gale is blowing from the east. The beach is not, however, a convenient place for observation at such a time, nor can it be visited save by observers resident in the neighborhood on account of floods and washouts that result and interrupt railroad and other travel. For this reason it is more practicable to study what occurs during spring tides with only moderate winds.

Such an ocasion was November 7, 1896 when I was fortunate enough to reach the beach shortly before high tide. The ordinary waves were playing up and down the bays as far as the belt of seaweed, *BB*, Fig. 2. These waves advanced with a front indented by the stony points at their maximum advance. But at intervals of about ten minutes a great wave broke evenly upon the line of seaweed, sending tons of water over the cobblestones above. The zone of seaweed in the diagram should be understood to have a depth of 12 to 18 inches. Shoreward from the crest, the weed slopes and thins. It is more or less present even on the cobble belt *AA*. But the zone represented on the diagram marks the crest. Immediately after breaking, the wave outside the zone *BB* retires, leaving considerable masses of water imprisoned behind the weed. This can only escape through occasional breaks in the wall of seaweed and at these points streams of considerable strength set outward. This moment is recorded in Fig. 3. The wave has just broken evenly along the whole line. At the instant represented by Fig. 3 the water may be seen pouring toward the opening from right and left behind the weed, streaming out through the break in the weed whence the water is distributed fan-like in every direction. A similar fan in the water to the left indicates the opening of another outlet through the weed. The quantity of water flung behind the weed barrier when such a great wave breaks is sufficient to maintain a strong current through the outlet during the rise and fall of several ordinary waves, which only play up and down the bays. As the great wave recedes we note the stony promontories, which are completely buried in Fig. 3, and the bays between. We also note that each break in the seaweed exactly marks a bayhead. The gravel cusps below are still beneath the water. On one occasion I saw a continuous wall of seaweed flung upon the beach, saw the water ponded behind it until finally weaker points in the wall yielded to the pressure and broke, and openings were established that guided the outflow of all subsequent great waves. It seems to be clear that the bays between the stony promontories are scoured out by water escaping from behind the barrier above. That weak points should occur is inevitable. It is not conceivable that the waves could cast up a line of weed so perfectly homogeneous as to present the same resistance to outflowing water all along the line. Once a current is established across the crest, its lightness causes the weed to float away in the stream until the pebbles below are bared, and then washed down the beach in the narrow rushing stream. The weed where unbroken protects the stony ridge as the paper pattern protects glass from the sand-blast. Furthermore it concentrates the water on the unprotected spots. It may be thought

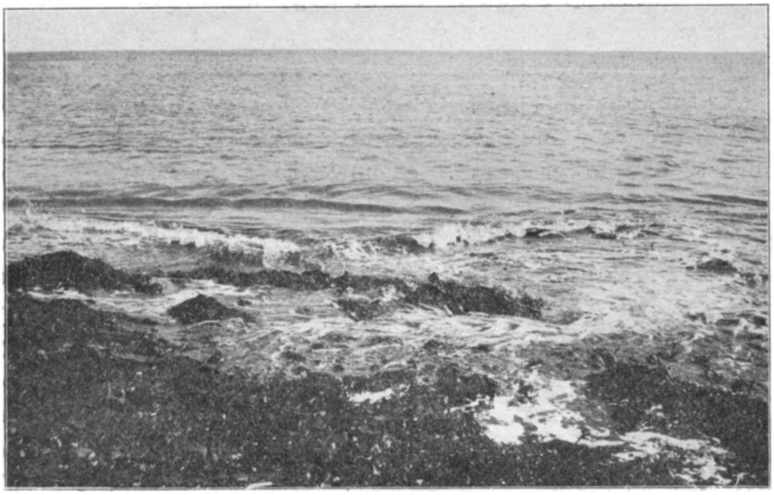

FIG. 3.—Moment of wave retreat.

that a stony barrier might play a similar part on a beach where seaweed was absent. Great waves would surmount the crest and the water caught behind escape as best it might to the sea. Low places would doubtless occur in the crest of the line and some water flow over them. But it is to be expected that the water would filter through the mass rather than wear channels, owing to the greater specific gravity of the barrier. It is unlikely that bays could be cut out in the stones under such circumstances. It would seem to follow that such stony cusps are to be looked for only on coasts where seaweed or some similar material is abundantly thrown up.

As the tide falls, presently the waves cease to surmount the crest of the weed and each wave in receding discloses more and more of the lower beach. It now becomes evident that the scouring waters that have been rushing down the bays have spread the gravel with which they are visibly loaded in a great fan at the mouth of the bay, fairly underlying the wave-fan seen in Fig. 3, outside the seaweed. It is a true fan delta built by the stream where its waters are checked by the relatively stagnant waters outside. As these deltas are built out in front of the bays it results that in this outer line of points bays occur opposite the points of the inner stony promontories. This is at once clear on the diagram (Fig. 2). Walking along the beach at low tide the delta fans are seen nearest and are more in evidence than the stony or original cusps above. These upper cusps may well be called *residual*, as they are remnants of a continuous line in which the bays have been scoured out here and there. At Lynn the residual cusps are stony but that is not essential. In Fig. 1, the whole material is apparently fine beach sand. The seaweed that originated the form is here hardly visible but enough is on hand to show that it occurs on the beach. Attention should be called here to the fact that seaweed shrinks enormously on drying. I have made no measurements and have no data at hand, but sugar-cane, with which I am familiar, contains nearly three times as much juice as wood, and cane has certainly more woody fiber than most seaweed. For this reason a heap of weed that may while fresh considerably modify the waves, may become quite inconspicuous when dry. Considerable quantities of weed are also carted from the beaches for manure. The only sure way to determine the presence or absence of seaweeds on a beach is to visit it immediately after on-shore storms have torn up the bottom just beyond the low tide mark. The residual cusps in Fig. 1 are rendered unusually visible by the wetting of a portion of their line in what seems to be an ordinary wave of a rising tide. The original photograph shows the delta cusps distinctly alternating with the residual cusps above. At Gay Head I have seen only the residual cusps, which are there constructed of pebbles an inch or two in diameter and derived from the till topping the cliff above. At that time the form was unintelligible to me, but now I am sure that at lower water the delta cusps will be seen at Gay Head too.

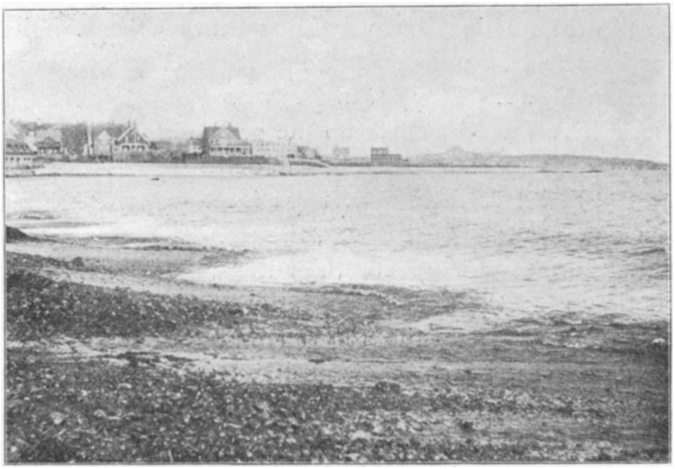

FIG. 4.—Residual and Delta Cusps.

In Fig. 4 both series are well shown on Lynn Beach. The water stands in the hollows between the delta cusps, which show only their points on the left. The view was taken about two hours after high water. Half an hour later the waves break far out on the beach, and only a steady trickle of water draining out of the ridge of stones and seaweed remains, in place of the violent rushing at high water. The contact of the delta cusps with the flat beach is now disclosed, and we see the cobbles already referred to strewn along the margin of the cusps (Fig. 5). The view is taken from a point on the edge of the flat beach itself and shows only the delta cusps, the residual cusps lying off farther to the left. The cobbles have probably come down the bays in the rushing streams that build the deltas. They are scattered quite at random at the foot of the delta slopes, as indicated in Fig. 2. The advancing waves of the next tide will doubtless drive some of them up the promontories on which the earlier waves are concentrated by the delta cusps.

But if the establishment of bays in the ridge of cobbles is to be ascribed to the great waves, the part of the ordinary wave is not therefore to be neglected, nor the waves of lesser tides so long as they send the water at all into the region affected. The ordinary waves intensify the form given by the gaps in the seaweed. Across the beach below all waves advance in long, even lines. As these come to the delta cusps their front is broken into tongues which are concentrated into the outer bays and made to impinge on the residual cusps in advance of the water which comes to the inner line of bays. Of all the details of the wave-work, this is one of the best established. As the wave thus concentrated on the stony promontories tries to surmount them, it is more and more deflected to right and left by the steepness of the cusps. Thus, when the wave recedes, almost all the water runs down the inner bays. This was first seen at Gay Head, where I have a record in photographs. The bays thus have a preponderance of seaward scour. On Lynn Beach this point was studied by gathering bricks along the shore and throwing them in front of the points of the stony promontories. Of twenty bricks cast into the sea where the two fans meet in Fig. 3, corresponding to the second stony point from the left in Fig. 2, one went across into the bay alongside with the next incoming wave; then a great wave brought all over the ridge of seaweed.

Some at once went on down into the bay alongside, whence they were finally removed seaward by the play of ordinary waves. Of a hundred stones flung into one of the bays, more than half were carried seaward in twenty minutes, and the others were half buried in the gravel by the scouring water digging pits in front of them. On another occasion my hat blew into the water in one of the bays, and in spite of some wind off-shore, was soon cast up on one of the promontories. There is some travel of material shoreward up the promontories and much travel down the bays toward the sea. The great wave drives a good deal of material on shore.

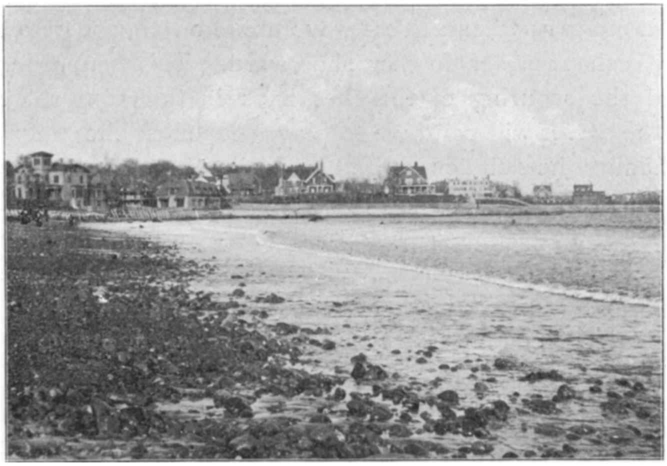

FIG. 5.—Delta Cusps and pebble fringe.

The cobbles that descend over the fan deltas to the beach margin, and again ascend the promontories at the next high water, do not necessarily return to the point in the stony belt above from which they descended. It is probable that with winds setting more or less obliquely along a beach the descents will be made constantly to the right or left of the descents. I think I have seen something of the sort on Lynn Beach, but the observations were not sufficiently continuous to make this certain. In this case each cobble is liable to travel *epicycling* along the beach, now up, now down, but always along in some lateral direction. In this form a short journey along the beach means a much longer journey along the actual path of travel, and longer opportunity for the attrition that comminutes all beach material.

On any beach where cusps occur the waves may be seen scouring out the bays and building fan cusps below. If it be asked how this begins, the answer must be that the beginning is as old as the beach. When first a ridge of cobbles was flung up by the waves and seaweed driven upon it with the rising tide, there came a moment when a great wave broke on the ridge crest to send a rush of water further shoreward. This water escaping guided the scouring of the first bays in the stony ridge. In these the waves will continue to play, deepening the scour ways, lengthening the delta cusps, and working over and modifying the mass till another spring tide or another on-shore gale builds a new barrier with stones and seaweed newly torn from the bottom, Each set of cusps may modify its successors. A new crest of seaweed flung up today is likely to have its weak points in some measure determined by the previous channels. In violent storms it is doubtful if this control is significant. Each storm probably sets the shape in which the waves must play for a long time.

As these studies have been made at a single beach, though confirmed by some observations from Gay Head and Narragansett Bay, corroboration or modification of the interpretation by others would be welcome.

MARK S. W. JEFFERSON.